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[Name of Document] SPECIFICATION

[Title of the Invention] DISPLAY DEVICE AND ELECTRONIC APPARATUS

[Claims]

[Claim 1] A display device having two transmissive polarization axis variable means, illumination means disposed between the two transmissive polarization axis variable means to emit light to the two transmissive polarization axis variable means, and two reflective polarized light selecting means, each disposed between the illumination means and each of the two transmissive polarization axis variable means, wherein the illumination means is able to transmit the reflected light from the two reflective polarized light selecting means.

[Claim 2] The display device according to Claim 1, wherein the reflective polarized light selecting means reflects linearly polarized light in a predetermined direction, while transmitting linearly polarized light in a direction intersecting the reflected polarized light, and wherein the two reflective polarized light selecting means are set in a direction in which the reflective polarization axes thereof intersect each other.

[Claim 3] The display device according to Claim 2, wherein two absorptive polarized light selecting means, for absorbing linearly polarized light in a predetermined direction, while transmitting linearly polarized light in a direction intersecting the absorbed polarized light, are interposed between the respective reflective polarized light selecting means and the respective transmissive polarization axis variable means, and wherein each of the reflective polarization axes of the reflective polarized light selecting means and each of the transmissive polarization axes of the absorptive polarized light selecting means intersect each other.

[Claim 4] The display device according to Claim 1, wherein each of the reflective polarized light selecting means comprises a cholesteric liquid crystal and reflects circularly polarized light with a predetermined rotating direction, while transmitting circularly polarized light with the opposite rotating direction, and wherein each of the two reflective polarized light selecting means reflects circularly polarized light with the same rotating direction.

[Claim 5] The display device according to Claim 4, wherein a λ/4 retardation film is disposed between the two reflective polarized light selecting means and the two transmissive polarization axis variable means.

[Claim 6] The display device according to any one of Claims 1 to 5, wherein the illumination means has a light source and a light guiding plate for guiding light from the light source and is able to emit the light from both sides of the light guiding plate to the transmissive polarization axis variable means.

[Claim 7] The display device according to Claim 6, wherein the birefringence the light guiding plate is about zero.

[Claim 8] The display device according to Claim 6, wherein the birefringence of the light guiding plate is λ/2, and wherein the angle formed between the slow axis of the light guiding plate and the reflective polarization axis of each reflective polarized light selecting means is set to be about 45°.

[Claim 9] A display device having two liquid crystal panels, a lighting unit disposed between the liquid crystal panels and capable of emitting light to each liquid crystal panel, and two reflective polarizers disposed between the lighting unit and each of the liquid crystal panels.

[Claim 10] The display device according to Claim 9, wherein the reflective polarizer reflects linearly polarized light in a predetermined direction, while transmitting linearly polarized light in the direction intersecting the reflected polarized light, and wherein the two reflective polarizers are set in a direction in which the polarization axes thereof intersect each other.

[Claim 11] An electronic apparatus comprising the display device according to any one of Claims 1 to 10.

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[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a display device and an electronic apparatus, and more specifically, relates to a display device that can display on both the front and the rear surfaces.

[0002]

[Description of the Related Art]

Display devices that have a backlight as a light source interposed between two liquid crystal panels and that can display on both the front and the rear surfaces have been known. These display devices are described in, for example, the Patent Document 1 or Patent Document 2.

[0003]

[Patent Document 1]

Japanese Unexamined Patent Application Publication No. 10-90678

[Patent Document 2]

Japanese Unexamined Patent Application Publication No. 2001-290445

[0004]

[Problems to be Solved by the Invention]

For the above display device, a polarizer is disposed between each of the two liquid crystal panels and the light source, allowing only light polarized in a predetermined direction to enter the display panels. In this case, light polarized in a direction that does not match the direction of the polarization axis (the transmissive axis) of the polarizer is absorbed by the polarizers. For this reason, the amount of light that may be used for the display is greatly reduced, causing the display to become dark. Therefore, to obtain a bright display, it is necessary to use a brighter light source. As a result, the electrical power consumption increases.

[0005]

The present invention is made to solve the above problem, and an object of the present invention is to provide a display device that can display on both the front and the rear surfaces by effectively using the backlight to offer a bright display without causing an increase in the electrical power consumption, ant to provide an electronic apparatus that includes the display device.

[0006]

[Means for Solving the Problems]

To achieve the above objects, the present invention provides a display device having two transmissive polarization axis variable means, illumination means disposed between the two transmissive polarization axis variable means to emit light to the two transmissive polarization axis variable means, and two reflective polarized light selecting means, each disposed between the illumination means and each of the two transmissive polarization axis variable means, wherein the illumination means is able to transmit the reflected light from the two reflective polarized light selecting means.

[0007]

In such a display device, among the light emitted from the illumination means, only the polarized light (referred to as first polarized light) selectively transmitted through the reflective polarized light selecting means (referred to as first reflective polarized light selecting means) enters the transmissive polarization axis variable means. On the other hand, the reflected light (referred to as second polarized light) polarized in a predetermined direction at the first reflective polarized light selecting means enters the reflective polarized light selecting means on the opposite side (referred to as second reflective polarized light selecting means) via the illumination means. By selectively transmitting the reflected light through the second reflective polarized light selecting means, the reflected light can enter the transmissive polarization axis variable means on the opposite side. More specifically, by configuring the second reflective polarized light selecting means so that it transmits the second polarized light while reflecting the first polarized light, the polarized light selectively reflected at one of the reflective polarized light selecting means is selectively transmitted through the other reflective polarized light selecting means. Then, this polarized light enters the transmissive polarization axis variable means and can be selectively emitted to the outside, allowing the light emitted from the illumination means to be used for display without any loss. Thus, for the display device, which can display on the front and the rear surfaces, bright display can be obtained by effectively using the light without causing an increase in the electrical power consumption. The reflective polarized light selecting means may comprise materials such as a composite of several different types of birefringent polymeric films alternately stacked in layers or a film utilizing the effect of circular dichroism of a cholesteric liquid crystal. Examples of the above reflective polarized light selecting means are optical films such as DBEF (product name) offered by the 3M Company.

[0008]

Here, the reflective polarized light selecting means reflects linearly polarized light in a predetermined direction, while transmitting linearly polarized light in a direction intersecting the reflected polarized light, and the two reflective polarized light selecting means are set in a direction in which the reflective polarization axes thereof intersect each other. In a case where the reflective polarized light selecting means that selectively reflect or transmit light according to the direction of the polarization axes thereof are used, by arranging the reflective polarization axes of the reflective polarized light selecting means to intersect each other (preferably at a 90°), the reflected light from one of the reflective polarized light selecting means can be efficiently transmitted through the other reflective polarized light selecting means.

[0009]

Furthermore, when the reflective polarized light selecting means, which selectively polarizes light based on the difference in the direction of the polarization axis, is applied as described above, absorptive polarized light selecting means that absorbs the polarized light with a polarization axis in a predetermined direction (hereinafter, also referred to as the absorptive polarization axis), while transmitting the polarized light with a polarization axis intersecting the absorbed polarized light (hereinafter, also referred to as the transmissive polarization axis) is formed between the reflective polarized light selecting means and the transmissive polarization axis variable means, and the reflective polarization axis of the reflective polarized light selecting means and the transmissive polarization axis of the absorptive polarized light selecting means can be set in the direction in which they intersect each other. In other words, at the absorptive polarized light selecting means, by once again selectively polarizing the light polarized at the reflective polarized light selecting means, the polarization selectivity of the transmissive polarization axis variable means for the incident light becomes higher, thus improving the display quality of the light emitted from the transmissive polarization axis variable means. In particular, since the absorptive polarized light selecting means generally has a higher polarization selectivity in comparison to the reflective polarized light selecting means, interposing the absorptive polarized light selecting means between the reflective polarized light selecting means and the transmissive polarization axis variable means increases the polarization selectivity for the light entering the transmissive polarization axis variable means.

[0010]

On the other hand, the reflective polarized light selecting means may be reflective circularly polarized light selecting means comprising a cholesteric liquid crystal, which utilizes the effect of circular dichroism to reflect the circularly polarized light with a predetermined rotating direction, while transmitting the circularly polarized light with the opposite rotating direction. In this case, the two reflective polarized light selecting means (the reflective circularly polarized light selecting means) may be arranged so that they each reflect circularly polarized light with the same rotating direction.

The reflective circularly polarized light selecting means comprising a cholesteric liquid crystal selectively reflects the circularly polarized light that enters with a predetermined rotating direction (a first rotating direction) with converting the rotating direction, whereas it selectively transmits the circularly polarized light that enters with a different rotating direction (a second rotating direction). In the case of the present invention, the rotating direction of the light is determined based on the direction in which the light travels.

Thus, by arranging two of the above reflective circularly polarized light selecting means so that they both reflect the circularly polarized light having the same rotating direction (for example, they both may reflect the circularly polarized light with the first rotating direction), the circularly polarized light with the first rotating direction is reflected at one of the reflective circularly polarized light selecting means and the rotating direction thereof is converted into the second rotating direction. Then, this polarized light is transmitted through the other reflective circularly polarized light selecting means and can be emitted to the transmissive polarization axis variable means.

More specifically, when two the reflective circularly polarized light selecting means are used, the rotating directions of the circularly polarized light reflected thereby are set in the same direction, whereby the light reflected at one of the reflective polarized light selecting means can be transmitted through the other reflective polarized light selecting means, as described above.

[0011]

In the case where the above reflective circularly polarized light selecting means is used, a λ/4 retardation film is interposed between the reflective circularly polarized light selecting means and the transmissive polarization axis variable means, whereby the circularly polarized light with a predetermined rotating direction that has been transmitted through the reflective circularly polarized light selecting means is converted into linearly polarized light in the direction parallel to the transmissive polarization axis of the transmissive polarization axis variable means, and this linearly polarized light is selectively emitted with its polarization axis converted at the transmissive polarization axis variable means.

[0012]

The illumination means includes a light source and a light guiding plate for guiding light from the light source and can emit the light from both sides of the light guiding plate to the two transmissive polarization axis variable means. With the illumination means, light can effectively be illuminated onto each of the transmissive polarization axis variable means by the simple structure.

[0013]

The birefringence of the light guiding plate may preferably be about zero. In this case, among the light emitted from the light guiding plate, the polarized light reflected back from one of the above reflective polarized light selecting means is transmitted through the light guiding plate while maintaining its state of polarization. Consequently, this polarized light can be transmitted through the other reflective polarized light selecting means. Therefore, the light is more efficiently used to provide a brighter display.

[0014]

On the other hand, the birefringence of the of the light guiding plate can be set to be λ/2, and the angle formed between the slow axis of the light guiding plate and each of the reflective polarization axes of each of the reflective polarization light selecting means can be set to about 45°. In this case, since the angle formed between the slow axis of the light guiding plate and the reflective polarization axes of the reflective polarization light selecting means is set to about 45°, the phase of the linearly polarized light, which was part of the illumination light emitted from the light guiding plate, reflected back from the reflective polarized light selecting means may be shifted by λ/2, causing the direction of the linearly polarized light to be rotated by 90°. In this case, even if the reflective polarization axes of the two reflective polarizers are disposed parallel to each other, the reflected light will definitely be transmitted through the other reflective polarized light selecting means.

[0015]

Next, to solve the above problem, the display device of the present invention is characterized by including two liquid crystal panels, a lighting unit, which is for illuminating both liquid crystal panels and which is interposed between the two liquid crystal panels, and two reflective polarizers, each interposed between the lighting unit and each of the two liquid crystal panels. In other words, the above transmissive polarization axis variable means are composed of liquid crystal panels, whereby the thickness of the display device (liquid crystal device) can be reduced. In this case, the reflective polarizers reflect linearly polarized light in a predetermined direction, while transmitting linearly polarized light in the direction that intersects the reflected polarized light. The two reflective polarizers may preferably be arranged in the direction in which the reflective polarization axes of the reflective polarizers intersect each other.

[0016]

Next, the electronic apparatus of the present invention is characterized by including the above display device. This electronic apparatus has low electric power consumption and a simple and easy structure that allows images to be displayed on both the front and the rear surfaces, and moreover, can provide bright display on both surfaces.

[0017]

[Description of the Embodiments]

An embodiment of the present invention will now be described below with reference to the drawings. To make the drawings shown in the embodiment easily viewable, the film thickness and the dimensional ratio of respective components are appropriately varied.

[0018]

[First Embodiment]

Fig. 1 is a sectional view showing the schematic structure of a liquid crystal display device which is a first embodiment according to the present invention. Fig. 2 illustrates the principle of display and includes only the components necessary for the description.

[0019]

As shown in Fig. 1, a liquid crystal display device 100 of this embodiment includes a pair of liquid crystal cells 10 and 20 and a backlight (lighting unit) 40 used for the liquid crystal cells 10 and 20. The liquid crystal display device 100 displays on the front and the rear surfaces by emitting light transmitted from the backlight 40 via the liquid crystal cells 10 and 20 onto display surfaces 1 and 2. In the liquid crystal cell 10 (20), an upper substrate 13 (24) and a lower substrate 14 (23) are disposed so that they face each other. In the space between the upper substrate 13 (24) and the lower substrate 14 (23), liquid crystal is sealed to form a liquid crystal layer 15 (25). The liquid crystal layers 15 and 25 of the liquid crystal cells 10 and 20 function as transmissive polarization axis variable means. The liquid crystal is a TN liquid crystal with a 90° twist angle. In addition, in this embodiment, the backlight-40-sides of the liquid crystal cells 10 and 20 are referred to as the 'back' sides (rear sides) and the opposite sides are referred to as the 'observation' sides (front sides).

[0020]

The backlight 40 is illumination means disposed on the rear sides of the liquid crystal cells 10 and 20. The backlight 40 includes a light source 42, which is composed of a component such as a cold-cathode tube or an LED, and a light guiding plate 41. The liquid crystal cells 10 and 20 can be irradiated with light from the longitudinal sides (the sides facing the liquid crystal cells 10 and 20) of the light guiding plate 41. An organic EL light, for example, can be used as the light source for the backlight 40 allowing light to be emitted from both sides of the backlight 40. In this case, since the organic EL light is a planar light source, it is not necessary to provide complex designs and/or processes to uniformly irradiate the front and the rear surfaces of the light guiding plate 41 with light emitted from the lateral side. In addition, moiré patterns caused by interference with the patterns of the light guiding plate do not occur as frequently. Furthermore, preferably, the light guiding plate 41 is composed of a material with a small birefringence such as acrylic resin, or fluorocarbon resin so that the state of polarization of the reflected polarized light is not altered easily.

[0021]

Reflective polarizers 31 and 32, which are reflective polarized light selecting means, are disposed between each of the two liquid crystal cells 10 and 20 and the backlight 40. The reflective polarizers 31 and 32 reflect linearly polarized light in a predetermined direction, while transmitting linearly polarized light in the direction intersecting the reflected polarized light. In this embodiment, the reflective polarizers 31 and 32 are set in a direction in which the reflection axes thereof intersect each other.

[0022]

An absorbing polarizer 11 (22) is disposed on the observation side of the liquid crystal cell 10 (20), and similarly, an absorbing polarizer 12 (21) is disposed on the backlight-40-side (the back side) of the liquid crystal cell 10 (20). In this case, the transmissive polarization axis of the absorbing polarizer 11 (22) is set in a direction substantially equal to the direction of the transmission axes of the reflective polarizer 31 and 32.

[0023]

In the liquid crystal cell 10 (20), pixel electrodes (not shown in the drawings), which are composed of transparent conductive films such as indium tin oxide (ITO), are disposed on the inner surface side of the lower substrate 14 (23), which is composed of a transparent material such as glass or plastic. An alignment film (not shown) composed of polyimide or the like is deposited on the pixel electrode. In this embodiment, the lower substrate 14 (23) is composed of a device substrate formed with pixel switching elements such as TFT's, data lines, and scanning lines. In Fig. 1, however, the pixel switching elements, data lines, and scanning lines are not shown.

[0024]

Meanwhile, on the inner surface side of the upper substrate 13 (24) composed of a transparent material such as glass or plastic, a common electrode (not shown) composed of a transparent conductive film such as indium tin oxide (ITO), and an alignment film (also not shown in the drawings) composed of polyimide or the like are stacked in sequence.

[0025]

The alignment film on the upper substrate 13 (24) and the lower substrate 14 (23) are processed by methods for a horizontal alignment such as rubbing. The alignment direction of each alignment film for the upper substrate 13 (24) and the lower substrate 14 (23) is set to intersect each other. The liquid crystal interposed between both the substrates is twisted by 90°. Applying a selective voltage (turning the voltage on), aligns the molecules of the liquid crystal layer 15, disposed between the upper substrate 13 (24) and the lower substrate 14 (23), in a direction perpendicular to the surfaces of the substrates. Incidentally, in this embodiment, the TN mode with a 90° twist angle is described as an example. The liquid crystal mode, however, is not limited to this mode, and other liquid crystal modes may be employed as well.

[0026]

In addition, the absorbing polarizer 12 (21) on the back side and the absorbing polarizer 11 (22) on the observation side are arranged so that the directions of their transmissive polarization axes intersect in the same way as the alignment directions of the above alignment films intersect. More specifically, as shown in Fig. 2, the transmissive polarization axis of the absorbing polarizer 12 (21) on the back side is substantially parallel to the alignment direction of the alignment film on the inside of the lower substrate 14 (23). At the same time, the axis is substantially parallel to the transmissive polarization axis of the reflective polarizer 31 (32). The transmissive polarization axis of the absorbing polarizer 11 (22) on the observation side is set to intersect (preferably at a 90° angle) the transmissive polarization axis of the absorbing polarizer 12 (21) on the observation side.

[0027]

The principle of display of the liquid crystal display device 100 of this embodiment will now be described with reference to Fig. 2. As shown on the left side in Fig. 2, the light emitted from the light guiding plate 41 to the first liquid crystal cell 10 (the front liquid crystal cell 10) is selectively polarized at the front reflective polarizer 31. In other words, polarized light (first polarized light) with a polarization axis parallel to the transmissive polarization axis (parallel to the plane of the drawing) of the reflective polarizer 31 is transmitted through the reflective polarizer 31, whereas polarized light (second polarized light) with a polarization axis parallel to the reflective polarization axis (perpendicular to the plane of the drawing) of the reflective polarizer 31 is reflected at the reflective polarizer 31.

[0028]

The first polarized light transmitted through the reflective polarizer 31 is then transmitted through the absorbing polarizer 12 (the transmissive polarization axis thereof is in a direction parallel to the plane of the drawing) on the back side of the liquid crystal cell 10. Subsequently, the first polarized light enters the liquid crystal layer 15, where its polarization axis is converted according to the application of a selective voltage. When the selective voltage is not applied (when the voltage is off), the first polarized light is transmitted through the liquid crystal layer 15 and its polarization axis is converted. Then it is further transmitted through the absorbing polarizer 11 (the transmissive polarization axis thereof is in a direction perpendicular to the plane of the drawing) on the observation side, causing the front display surface (a first display surface) to be bright (white). Conversely, when the selective voltage is applied (when the voltage is on), the first polarized light is transmitted through the liquid crystal layer 15 without its polarization axis being converted, but then it is absorbed by the absorbing polarizer 11 on the observation side, causing the display to be dark (black).

[0029]

The second polarized light reflected at the reflective polarizer 31 is transmitted through the light guiding plate 41 and then enters the rear reflective polarizer 32. In this case, since the light guiding plate 41 is composed of a material with a small birefringence (preferably with no birefringence) as mentioned above, the polarization axis of the second polarized light is not converted as it is transmitted through the light guiding plate 41.

[0030]

Since the reflective polarization axis of the rear reflective polarizer 32 is set to intersect the reflective polarization axis of the front reflective polarizer 31, the second polarized light that enters the rear reflective polarizer 32 is transmitted through this reflective polarizer 32 and then transmitted through the absorbing polarizer 21 on the back side (the transmissive polarization axis is in a direction perpendicular to the plane of the drawing) of the second liquid crystal cell 20 (the rear liquid crystal cell) to enter the liquid crystal layer 25. At this liquid crystal layer 25, the polarization axis is converted according to the application of the selective voltage. When the selective voltage is not applied (the voltage is off), the second polarized light is transmitted through the liquid crystal layer 25 and its polarization axis is converted. Then, it is transmitted through the absorbing polarizer 22, (the transmissive polarization axis thereof is in a direction parallel to the plane of the drawing), causing the rear display surface (a second display surface) to be bright (white). Conversely, when the selective voltage is applied (the voltage is on), the second polarized light is transmitted through the liquid crystal layer 25 without its polarization axis being converted, but then it is absorbed by the absorbing polarizer 22 on the observation side, causing the display to be dark (black).

[0031]

On the other hand, similarly, as shown on the right side in Fig. 2, the light emitted from the light guiding plate 41 to the rear liquid crystal cell 20 is also selectively polarized at the rear reflective polarizer 31. Here, the light transmitted through the reflective polarizer 32 is third polarized light, and the light reflected at the reflective polarizer 32 is fourth polarized light. The transmitted third polarized light can be emitted to the rear display surface (the second display surface) via the liquid crystal cell 20. Furthermore, the reflected fourth polarized light can be emitted to the front display surface (the first display surface) via the front reflective polarizer 31 and the liquid crystal cell 10, whereby images can be displayed on both the front and the rear surfaces.

[0032]

As described above, in this embodiment, the polarized light reflected at one of the reflective polarizers (for instance, the reflective polarizer 31) can be transmitted through the other reflective polarizer (for instance, the reflective polarizer 32). As a result, the light utilization efficiency is improved, and the brightness of both the front and the rear surfaces of the liquid crystal panel is increased. In addition, since two liquid crystal panels can be illuminated with one light guiding plate, the reduction in thickness of the liquid crystal display device can be achieved, and the number of parts of the device can be reduced.

[0033]

Incidentally, although the birefringence of the light guiding plate 41 was about zero in this embodiment, the birefringence of the light guiding plate 41 may be $\lambda/2$, while the slow axis of the light guiding plate 41 may form an angle of about 45° with the reflective polarization axis of each of the reflective polarizers 31 and 32. Moreover, the reflective polarization axis of each of the reflective polarizers 31 and 32 can be parallel to each other. When the angle formed between the slow axis of the light guiding plate 41 and the reflective polarization axis of each of the reflective polarizers 31 and 32 is set to be about 45°, the linearly polarized light, which was part of the light emitted from the light guiding plate 41 and which was reflected back from either one of the reflective polarizers 31 and 32, is securely transmitted through the other transmissive polarizer since the phase of the respective linearly polarized light is shifted by λ/2. As described here, by controlling the birefringence of the light guiding plate and the directions of the axes, the angle of the reflective polarization axis of each reflective polarizer can be rotated 90°.

[0034]

[Second Embodiment]

Fig. 3 is a sectional view showing the schematic structure of the liquid crystal display device of a second embodiment, and Fig. 4 illustrates its principle of display and shows only the components necessary for the description. For components that are indicated by the same reference numerals as the liquid crystal display device 100 of the first embodiment shown in Fig. 1, the structures of these components are the same as the ones shown in Fig. 1 unless otherwise stated.

[0035]

Similar to the first embodiment in Fig. 1, the liquid crystal display device 200, as shown in Fig. 3, includes two liquid crystal cells 10 and 20 and a backlight (lighting unit) 40 used for both the liquid crystal cells 10 and 20, and displays images on both the front and the rear surfaces by emitting light transmitted from the backlight 40 via the liquid crystal cells 10 and 20 onto the display surfaces 1 and 2.

[0036]

Reflective polarizers 35 and 36, which are reflective polarized light selecting means, are each interposed between the backlight 40 and each of the liquid crystal cells 10 and 20, respectively. The reflective polarizers 35 and 36 are composed of cholesteric liquid crystal. These polarizers reflect circularly polarized light rotating in a predetermined direction, while transmitting circularly polarized light rotating in the opposite direction. In this embodiment, the rotating directions of the circularly polarized light reflected by both of the reflective polarizers 35 and 36 are set to the same direction. More specifically, the circularly polarized light reflected at the reflective polarizer 35 can be transmitted through the other reflective polarizer 36.

[0037]

On the back side of the liquid crystal cell 10 (20), i.e. on the back side of the absorbing polarizer 12 (21), a λ/4 retardation film 16 (26) is disposed. In this case, the retardation axis of the λ/4 retardation film 16 (26) is arranged so that the circularly polarized light, after being transmitted through the λ/4 retardation film 16 (26), becomes linearly polarized light that can be transmitted through the absorbing polarizer 12 (21).

[0038]

The principle of display of the liquid crystal display device 200 according to this embodiment will now be described with reference to Fig. 4. Incidentally, the rotating directions of the circularly polarized light shown below are the rotating directions viewed from the direction opposite to that in which the light travels.

[0039]

First, as shown on the left in Fig. 4, the light emitted from the light guiding plate 41 to the first liquid crystal cell 10 (the front liquid crystal cells 10) is selectively polarized at the front reflective polarizer 35. More specifically, at the reflective polarizer 35, the left-circularly-polarized light (first polarized light) is transmitted through the reflective polarizer 35, while the right-circularly-polarized light (second polarized light) is reflected at the reflective polarizer 35. After being reflected, the reflected circularly polarized light becomes left-circularly-polarized light (third polarized light).

[0040]

The first polarized light transmitted through the reflective polarizer 35 is transmitted through the λ/4 retardation film 16 disposed on the back side of the liquid crystal cell 10 and becomes linearly polarized light with a polarization axis in a direction parallel to the plane of the drawing. This linearly polarized light is further transmitted through the absorbing polarizer 12 (the transmissive polarization axis thereof is in a direction parallel to the plane of the drawing) and then enters the liquid crystal layer 15, at which the polarization axis is converted according to the application state of the selective voltage. When the selective voltage is not applied (when the voltage is off), the first polarized light is transmitted through the liquid crystal layer 15 with conversion of the polarization axis thereof. Then, it is transmitted through the absorbing polarizer 11 (the transmissive polarization axis thereof is in a direction perpendicular to the plane of the drawing) on the observation side, causing the front display surface (a first display surface) to be bright (white). Conversely, when the selective voltage is applied (when the voltage is on), the first polarized light is transmitted through the liquid crystal layer 15 without its polarization axis being converted, but then it is absorbed by the absorbing polarizer 11 on the observation side, causing the display to be dark (black).

[0041]

The second polarized light reflected at the reflective polarizer 35 is transmitted through the light guiding plate 41 and then enters the rear reflective polarizer 36. In this case, since the light guiding plate 41 is composed of a material with a small birefringence (preferably with no birefringence), as mentioned above, the rotating direction of the circularly polarized light is not altered when it is transmitted through the light guiding plate 41.

[0042]

The rear reflective polarizer 36 is arranged so that the rotating direction of the light it reflects intersects the rotating direction of the light reflected at the front reflective polarizer 35. Thus, the second polarized light that entered the rear reflective polarizer 36 is transmitted through the reflective polarizer 36 and then through the $\lambda/4$ retardation film 26 disposed on the back side of the second liquid crystal cell 20 (the rear liquid crystal cell). At the λ/4 retardation film 26, the second polarized light is converted into linearly polarized light with a polarization axis in a direction parallel to the plane of the drawing. The linearly polarized light is further transmitted through the absorbing polarizer 21(the transmissive polarization axis thereof is in a direction parallel to the plane of the drawing) and enters the liquid crystal layer 25. At this liquid crystal layer 25, the polarization axis is converted according to the application state of the selective voltage.

[0043]

When the selective voltage is not applied (when voltage is off), the second polarized light is transmitted through the liquid crystal layer 25 and its polarization axis is converted. Then, it is transmitted through the absorbing polarizer 22 (the transmissive polarization axis thereof is in a direction perpendicular to the plane of the drawing) on the observation side, causing the rear display surface (a second display surface) to be bright (white). Conversely, when the selective voltage is applied (when the voltage is on), the second polarized light is transmitted through the liquid crystal layer 25 without its polarization axis being converted, but then it is absorbed by the absorbing polarizer 22 on the observation side, causing the display to be dark (black).

[0044]

On the other hand, as shown in the right side in Fig. 2, the light emitted from the light guiding plate 41 to the rear liquid crystal cell 20 is also selectively polarized at the rear reflective polarizer 36. Here, left-circularly-polarized light (the third polarized light) is transmitted through the reflective polarizer 36, while right-circularly-polarized light (fourth polarized light) is reflected at the reflective polarizer 36. This reflected light becomes left-circularly-polarized light (the first polarized light).

[0045]

The third polarized light transmitted through the reflective polarizer 36 can be emitted onto the rear display surface (the second display surface) via the liquid crystal cell 20. In addition, the reflected first polarized light can be emitted onto the front display surface (the first display surface) via the front reflective polarizer 35 and the liquid crystal cell 10, whereby images can be displayed on both the front and the rear surfaces.

[0046]

As described above, this embodiment also includes reflective polarizers that are composed of a cholesteric liquid crystal utilizing the effect of dichroism of the circularly polarized light. By selectively polarizing the circularly polarized light according to its rotating direction, the polarized light reflected at one of the reflective polarizers (for instance, the reflective polarizer 35) can be transmitted through the opposite reflective polarizer (for instance, the reflective polarizer 36). As a result, light utilization efficiency is improved, and the brightness of the front and the rear surfaces of the panel increases. In addition, since two liquid crystal panels can be illuminated with one light guiding plate, reduction in thickness of the liquid crystal display device can be achieved, and the number of parts can be reduced.

[0047]

[Third Embodiment]

Next, an electronic apparatus of a third embodiment according to the present invention will be described with reference to Figs. 5 and 6. A cellular phone 1000, which is one embodiment of the electronic apparatus of the present invention, is a foldable cellular phone that may take a folded state, as shown in Fig. 5, and a use state, as shown in Fig. 6. The cellular phone 1000 includes a body 1001 and a display 1002.

[0048]

The above liquid crystal display device 100 (or the liquid crystal display device 200) is disposed inside the display 1002. Display images are visible on the front display surface 1003 and the rear display surface 1004 on the display 1002. For this cellular phone 1000, bright display images become visible on the front display surface 1003 and/or the rear display surface 1004 in response to the various operations and different states of the apparatus, including, in particular, the change from the folded state to the extended state, and vice versa.

[0049]

While the liquid crystal display device according to the display device of the present invention and the embodiment of the cellular phone according to the electronic apparatus of the present invention are both described above, the present invention is not limited thereto and various modifications can be added as long as the modifications do not deviate from the gist of the present invention.

[Brief Description of the Drawings]

[Fig. 1] Fig. 1 is a sectional view showing the schematic structure of a liquid crystal display device according to a first embodiment of the present invention.

[Fig. 2] Fig. 2 is an explanatory view showing the principle of display of the liquid crystal display device of Fig. 1.

[Fig. 3] Fig. 3 is a sectional view showing the schematic structure of a liquid crystal display device according to a second embodiment of the present invention.

[Fig. 4] Fig. 4 is an explanatory view showing the principle of display of the liquid crystal display device of

Fig. 3.

[Fig. 5] Fig. 5 is a perspective view showing the folded state of an electronic apparatus according to a third embodiment of the present invention.

[Fig. 6] Fig. 6 is a perspective view showing the use state of the electronic apparatus of Fig. 5.

[Reference Numerals]

100, 200 liquid crystal display device; 10, 20 liquid crystal cell (transmissive polarization axis variable means); 11, 12, 21, 22 absorbing polarizer (absorptive polarized light selecting means); 31, 32, 35, 36 reflective polarizer (reflective polarized light selecting means); 15, 25 liquid crystal layer (transmissive polarization axis variable means); 40 back light; 41 light guiding plate; 42 light source